**Comments for Notice of Inquiry ET Docket No. 02-380:**

**"Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band"**

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The TV spectrum sharing portion of this NOI discusses concepts remarkably similar to those developed at Georgia Institute of Technology School of Electrical and Computer Engineering by Allen J. Petrin and Paul G. Steffes since January 2001. Presentations given in April 2001 at GTBI (Georgia Tech Broadband Institute) annual meeting (Atlanta, GA) and in September 2001 to the GCATT (Georgia Center for Advanced Telecommunications Technology) Technology Policy Advisory Board by Allen Petrin proposed a frequency-agile spectrum aware network that would transparently share the TV spectrum with the aid of GPS, licensed user databases and sophisticated media access control protocols. Furthermore a paper describing this concept was disseminated internally at Georgia Institute of Technology and to several employees of the FCC and other government agencies. A version of this paper dated March 2002 is attached to this comment.

**Spectrum Sharing:**

Spectrum usage can be defined relative to several different variables: frequency, time, polarization (either linear or circular), space (latitude, longitude, altitude), and azimuth (also known as angle of arrival). With the proper wireless access device these variables can be used to share spectrum, increasing its utility. Furthermore the location type in which spectrum is used in can be divided into urban, suburban, rural areas with each having distinctive spectrum usage characteristics. Tailoring wireless access devices to a specific environment can result in increased performance while protecting the other users from destructive congestion.

**Sharing in the Unlicensed Bands:**

Sharing in the unlicensed bands by spread spectrum techniques with a fixed maximum transmit power allows for sharing of spectrum in both time and frequency. Spread spectrum is a good sharing technique when independent users access spectrum randomly in time and over varying bandwidths. One of the major disadvantages of this type of sharing is interference between spectrum users that results in either permanent loss of transmitted data or the need to resend data that has been corrupted. This limits both the transmission efficiency of the unlicensed bands and their quality of service. Frequency hopping and similar technologies that transmit with little regard to the spectral environment share similar impediments.

Placing a fixed maximum transmit power on all users limits the diversity of services provided by devices using the unlicensed bands. The requirements for a fixed wireless network are quite different from those of a highly mobile network. The former application could benefit from directional antennas and higher power, while the latter requires omni-directional antennas and has limited transmit power capability. Both networks can coexist even if the power they transmit and the gain of their antennas is different.

**Smart Sharing:**

Moving past spread spectrum sharing to smart sharing techniques for the unlicensed bands can result in improved utility with often minimal increased device cost. Smart sharing places additional intelligence into the wireless accesses device. The software component that governs how a device accesses its physical network connection is known as the media access control (MAC). Providing the MAC with more situational awareness and with well-developed protocols can increase its ability to maximize the utility of spectrum. Location (latitude, longitude, altitude), knowledge of spectral users attributes, geographic terrain and past spectral usage and restriction, are all elements of situational awareness used in a smart radio.

The global positioning system (GPS) can provide both location and time with high precision. With the integration of GPS receivers into mobile phones, costs have declined significantly as has their power requirement. Recent technological advances with GPS receivers has made them sensitive enough to be used indoors even when located under concrete floors or encased in metal boxes. [1]

Knowledge of other spectral users is crucial to preventing interference and maximizing the usage of underused spectrum in both licensed or unlicensed bands. Location of receivers and transmitters, transmission power, modulation type, receiver sensitivity, and antenna characteristics for both licensed and unlicensed users is information that can be placed in a database that can be continually updated. Also a smart radio can gather this information on its own or with the assistance of other compatible network elements to improve and update their databases. Usage of spectrum for a specific location over time can be used to predict future spectral usage (by periodic users) and to determine when the spectrum is free for use. This reduces both interference and increases quality of service for all spectrum users.

In a TV spectrum, knowledge of the modulation used can greatly assist a smart radio in deciding if a region of the spectrum in unoccupied. With the NTSC (National TV Standards Committee) format, the video carrier's center frequency has the highest relative power. A smart radio can assume that a TV signal is presently using the full channel if it detects a signal at an assigned center frequency even though it cannot detect the entire TV signal. Similarly if the smart radio can only detect the chrominance sub-carrier or the audio sub-carrier (both relatively high power), it can assume that the full channel is occupied. Since digital TV also uses a vestigial transmit format, the smart radio can look for the center frequency (which has higher relative power) to determine if the channel is in use.

Terrain, vegetation and manmade structures surrounding the smart radio can drastically reduce its view of the spectral environment. If the smart radio has knowledge of its

surroundings it can predict with the help of propagation models the locations where it lacks sufficient sensitivity to allow for dense spectrum reuse.

A well-developed control system uses feedback to maintain desired characteristics in an unknown and changing environment. A smart radio that is alerted to its spectral usage by other network elements can change its transmission in real-time to prevent interference once it has been detected. This is much preferable to using conservative worst-case models before a system is deployed to prevent interference, since real-time sensing guarantees that interference will not be a persistent occurrence.

Smart radios can be used in licensed environments, unlicensed environments or in shared environments. They provide increased utility for all of these situations.

**Current Usage in the 2.4 GHz Unlicensed Band:**

Measurements of spectrum usage in the 2.4 – 2.5 GHz band were taken on a weekday afternoon in midtown Atlanta, Georgia over a 150 minute period to quantify usage in the one of the unlicensed bands. Figure 1 presents a waterfall plot of the usage with 181,502 data points. This plot clearly depicts spectral usage in time, frequency, and power by scanning the spectral environment twice a minute. Figure 2 uses this data to plot the percentage of time that the spectrum is in use, its duty cycle, for varying amounts above the thermal noise floor of the receiving system. To better visualize this information Figure 3 takes three vertical slices of Figure 2 at the 3 dB, 7 dB and 10 dB points above the noise floor. Channel 1, 6, and 11 of the IEEE 802.11b wireless networking standard are superimposed over this plot; the arrows with each channel depict the 22 MHz bandwidth occupied by 802.11b users when transmitting at 11 Mbps.[2] These channels are typically used since they don't overlap in frequency. Figure 3 shows that the three 802.11b channels experience usage between 90% to 70%, a very high level. The severity of congestion of this spectrum is increased by the fact the 802.11b standard can never achieve 100% utilization.[3, 4] This data shows that there presently are locations that are presently saturated with local wireless network users. Hence it is reasonable to assume

that more unlicensed spectrum is required to satisfy the demands of wireless networks users.

**Astronomy and Wireless Medical Telemetry Protection:**

The risk to interfering with the Radio Astronomy Services (RAS) and the Wireless Medical Telemetry Service (WMTS) in TV channel 37 outweighs any benefit that could be achieved by sharing this channel any further. Radio astronomers are using the 608 – 614 MHz band (channel 37) to investigate changes in the polarization angle from extraterrestrial sources.[5] Channel 37 is in the center of one of three carefully selected bands employed for this detection technique. WMTS provides a vital primary communication service for healthcare facilities. This service continues to experience significant growth and is moving quickly to dramatically increasing its use of this band.

**Spectrum Policy Research at Georgia Institute of Technology:**

Research being performed by Allen J. Petrin and Paul G. Steffes in the School of Electrical and Computer Engineering consists of investigating methods to increase spectrum utilization and to avoid interference to incumbent users. Of particular interest is the 500 MHz to 6 GHz frequency range, which offers good propagation characteristics and the availability of low cost equipment. A spectrum study is currently being performed to determine spectral usage in this band with regard to frequency, time, polarization, and azimuthal direction for urban, suburban and rural locations. The usage data is being mined to determine usage patterns and the feasibility for a frequency-agile smart radio.
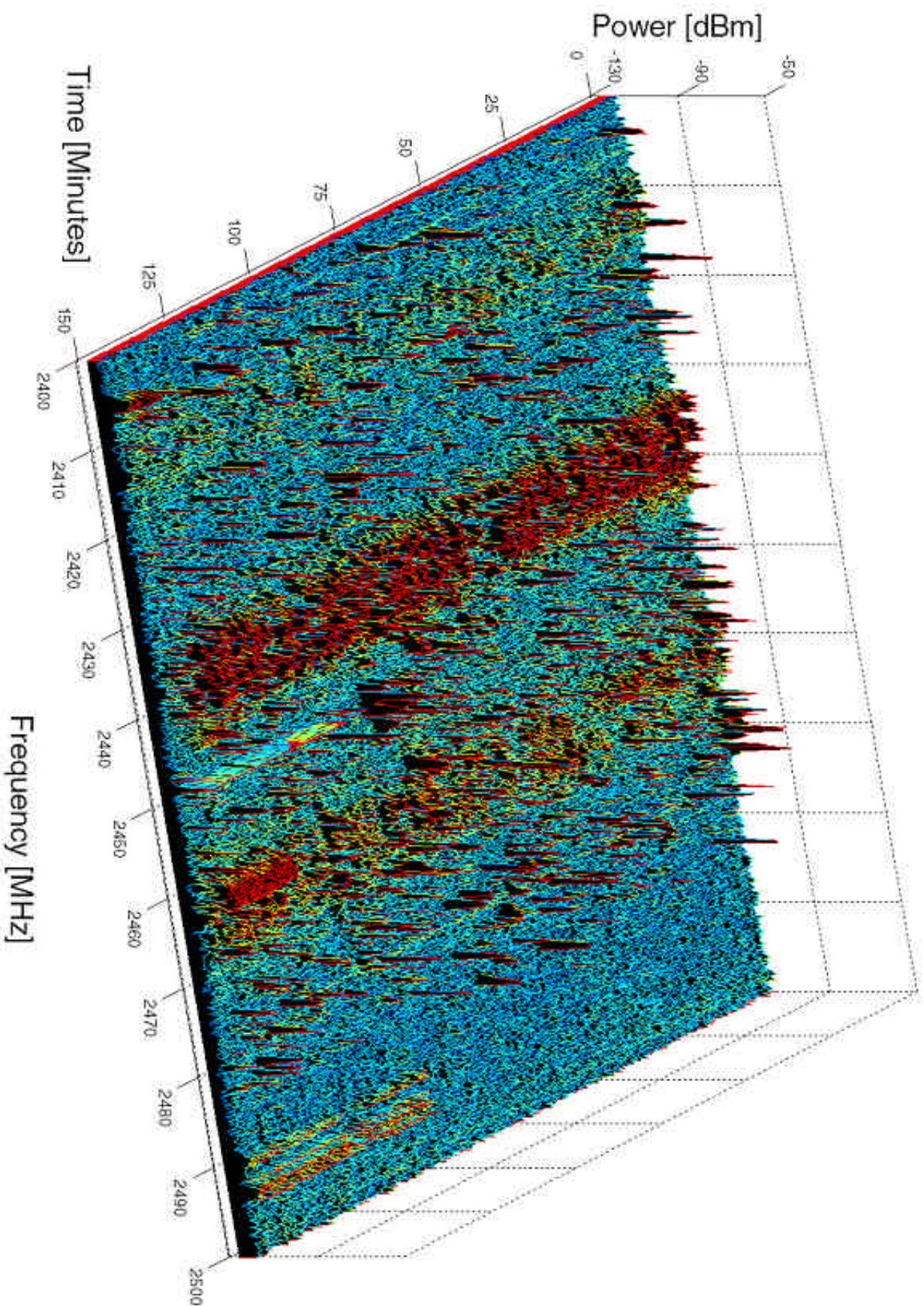
**Figure 1**

Power [dBm]

Time [Minutes]

Time Usage Proflie

Frequency [MHz]

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**Time Usage Profile: Duty Cycle**

Usage [%]

dB Above Noise Floor

Frequency [MHz]

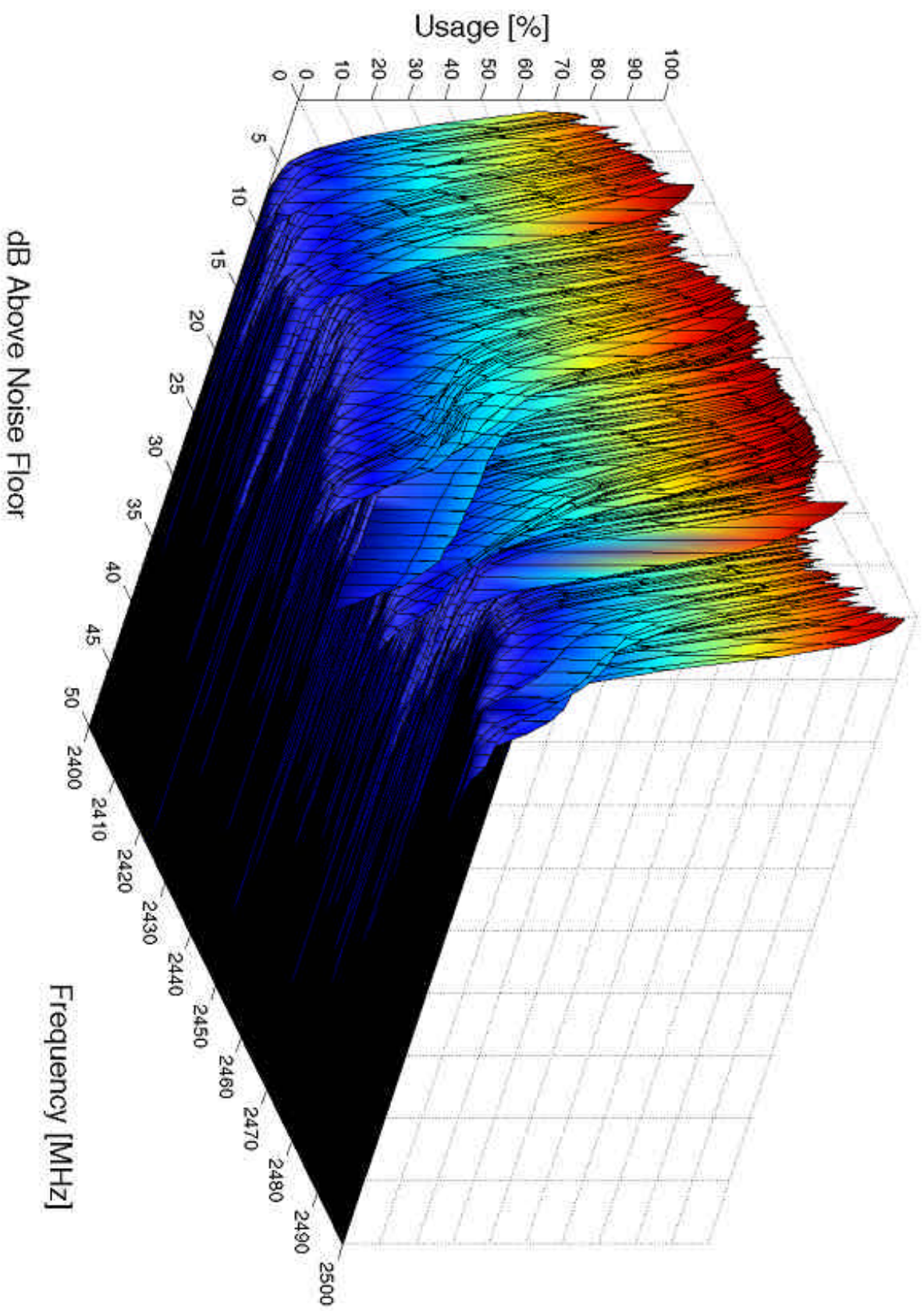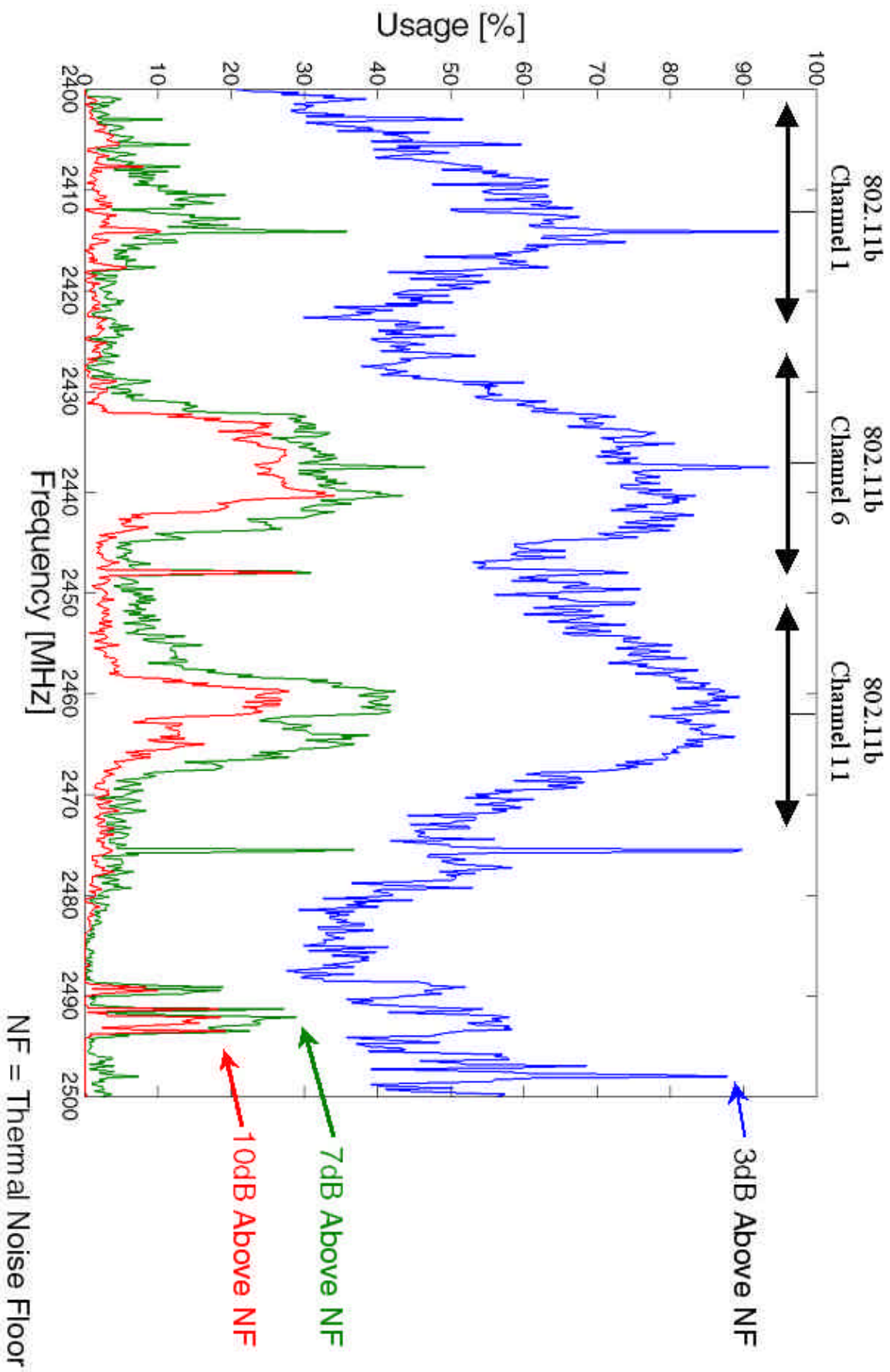**Figure 2**

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Figure 3

[1] F. van Diggelen, "Indoor GPS theory & implementation," in Proc. IEEE Position Location and Navigation Symposium, pp. 240-247, 2002.

[2] Wireless LAN Medium Access Control (MAC) and Physical (PHY) Layer Specification. IEEE Standard 802.11, IEEE, June 1999.

[3] I. Chlamtac, A.D. Myers, V.R. Syrotiuk, G. Zaruba, "An adaptive medium access control (MAC) protocol for reliable broadcast in wireless networks," in Proc. Int. Conf. on Communications, vol. 3, pp. 1692–1696, 2000.

[4] M. Natkaniec, A.R. Pach, "An analysis of the backoff mechanism used in IEEE 802.11 networks," in Proc. Intl. Symp. on Computers and Communications, pp. 444-449, July 2000.

[5] "CRAF Committee on Radio Astronomy Frequencies Handbook for Radio Astronomy – 2nd edition", Dwingeloo, Netherlands: Committee on Radio Astronomy Frequencies (CRAF), 1997, ch. 5, pp. 58-61.

**Author:**

Allen Petrin (me@allenpetrin.com) received his B.S. in computer engineering from the New Jersey Institute of Technology. He currently is a doctoral candidate in Electrical and Computer Engineering at the Georgia Institute of Technology, with a research focus in spectrum policy.